REMARKS

Claims 35-37, 39-41, 43-58 are pending in the present application. Claim 35 is amended herein to clarify that that the layer of reactive metal is comprised of a different metal from *any* metal present in the metal nitride. For example, if the reactive metal is aluminum, the metal nitride can not comprise aluminum. Applicants submit that this amendment is fully supported by Claim 35 as originally filed and does not add new matter. Each of the points raised by the Examiner are discussed below.

Election/Restriction

The Examiner stated that "This application contains claims 1-34 drawn to an invention non-elected with traverse..." and indicated that a complete reply must include cancellation of the non-elected claims.

Applicants respectfully point out that the non-elected claims, Claims 1-34, were cancelled in the Supplementary Response filed on August 4, 2003. The Office Action explicitly confirms entry of the Supplementary Response on August 5, 2003. Applicants reaffirm the prior cancellation of Claims 1-34.

Claim Rejections Under 35 U.S.C. §102

The Examiner maintained the rejection of Claims 35-37, 39-42 and 45 as anticipated by McTeer (U.S. Patent No. 6,204,179). In maintaining the rejections, the Examiner found that all of the presently recited limitations are taught or suggested by McTeer. Applicants disagree.

Claim 35, as amended, recites a barrier layer comprising a metal nitride layer directly covered by a layer of reactive metal and wherein the grain boundaries of the metal nitride layer are stuffed with a metal compound of a reactive metal that is *different* from each metal in the metal nitride. In a preferred embodiment, the barrier layer comprises a TiN layer. The grain boundaries of the TiN layer are stuffed with aluminum oxide. Aluminum is a reactive metal that is different from the metal in the metal nitride (TiN) layer, titanium. Claim 35 particularly recites that the *grain boundaries* are stuffed with a metal compound; the metal nitride layer that is uniformly doped with oxygen does not suggest this structure.

There is no teaching of the claimed barrier layer in McTeer. Importantly, a barrier layer merely having the elements Ti, N, and Al, such as the $Ti_xAl_yN_z$ layer disclosed in McTeer, does not meet the claim because the claim is directed to a *particular structure.* That is, the claim requires a specific arrangement of a metal nitride and a metal compound comprising a reactive metal different from the metal in the metal nitride. In particular, the claim requires that a metal nitride be present in a form such that it forms grain boundaries. Further, in the structure the grain boundaries must be stuffed with the metal compound, where the metal is different from any metal defining the grains.

McTeer's disclosure of a layer comprising Ti, Al and N, without more, can not meet these requirements. The Examiner does not identify a particular metal nitride that provides the "grain boundaries of the metal nitride." Without identification of the composition of "the metal nitride," Applicants cannot determine what in McTeer serves as the recited metal compound made from a reactive metal *different from the metal in the metal nitride.* Applicants submit that if the Examiner undertook this analysis, it would be clear that McTeer does not teach or suggest the structure of Claim 35.

Even if the layer is oxidized, as disclosed in McTeer, there is no teaching to indicate that the layer meets the requirements of Claim 35. Again, there is no identification of the composition of a particular metal nitride in the layer, of a structure comprising grain boundaries, or of the composition of a different metal compound that could stuff grain boundaries.

Even if the $Ti_xAl_yN_z$ is considered to be "the metal nitride," there is no teaching to suggest that subsequent oxidation can produce a metal nitride with grain boundaries stuffed with a *different* metal compound. First, there is no *different* metal available to react with the oxygen to stuff the boundaries; all of the available metal would be a metal from the metal nitride layer itself. In addition, there is no teaching or suggestion that the layer comprises identifiable grain boundaries at all, to say nothing of grain boundaries stuffed with a metal compound of a reactive metal different from the metal nitride that forms the grains.

As there is no explicit teaching or suggestion of stuffed grain boundaries in McTeer, it appears that the Examiner's rejection relies on 'inherency'; that is, the Examiner is concluding that the process of McTeer ***must*** produce a diffusion barrier comprising a metal nitride layer with stuffed grain boundaries. As Applicants pointed out in their prior Supplemental Response,

inherency requires that the prior art ***necessarily*** achieves the claimed result. "Inherency, however, may not be established by probabilities or possibilities. The fact that a given thing ***may*** result from a given set of circumstances is not sufficient." *In re* Oelrich, 666 F.2d 578, 581, 212 U.S.P.Q. 323, 326 (CCPA 1981). As discussed below, no process disclosed in McTeer will result in a diffusion barrier comprising a metal nitride layer with stuffed grain boundaries as claimed. Thus, Claim 35 can not be anticipated either explicitly or inherently.

In responding to Applicant's prior arguments regarding inherency, the Examiner asserts that since the process disclosed in McTeer is the same as Applicants and Applicants state that their process produces stuffing, it follows that the McTeer process would invariably produce stuffing as well. However, the Examiner's conclusion is based on the finding that McTeer discloses the same process for forming a barrier layer that is taught by Applicants. To the contrary, McTeer does ***not*** disclose the same process taught by Applicants and there is no teaching in McTeer that would produce a barrier layer with stuffed grain boundaries as claimed.

As the Examiner points out, in one embodiment McTeer teaches oxidizing a $Ti_xAl_yN_z$ barrier layer. However, as discussed above, this would not produce the claimed barrier layer. In the oxidation reaction, some nitrogen in the $Ti_xAl_yN_z$ compound is replaced with oxygen. The resulting $Ti_xAl_yN_{z-m}O_m$ does not stuff the grain boundaries of a metal nitride. Rather, the metal nitride itself is uniformly doped with oxygen. Moreover, there is no metal compound formed from a reactive metal that is *different* from each metal in the metal nitride, as claimed. Rather, the oxygen is reacting with a metal that *is present in the metal nitride.* As a result, this embodiment does not teach the claimed diffusion barrier explicitly or inherently.

In addition, there is no teaching of annealing the oxidized $Ti_xAl_yN_z$ layer *covered by a layer of reactive metal.* While it is true that McTeer teaches annealing the $Ti_xAl_yN_z$ barrier layer after oxygen doping and copper deposition (column 17, lines 22-58), *the barrier layer is not covered with a layer of reactive metal.* Copper is not one of the reactive metals in Claim 35, and the present specification teaches that copper is not reactive such as to migrate into the grain boundaries. Thus, when copper is subsequently deposited over the $Ti_xAl_yN_z$ barrier layer, annealed and caused to reflow, as disclosed in McTeer, the grain boundaries are not and can not be stuffed with a metal compound of a reactive metal, even though there is oxygen in the barrier layer.

Applicants recognize that *in a second embodiment*, McTeer teaches that the copper diffusion barrier may be any metal nitride. In this embodiment an aluminum wetting layer is deposited over a metal nitride layer (column 17, line 59 through column 18, line 9), which can be $Ti_xAl_yN_z$. Copper is subsequently deposited over the aluminum wetting layer and the whole structure is annealed. Importantly, however, there is no teaching of providing oxygen or nitrogen to the metal nitride layer (or any other species that could react with aluminum). As a result, the grain boundaries of the metal nitride layer *can not and will not be stuffed with an aluminum compound*. Rather, the aluminum wetting layer reacts to form an alloy with *the overlying copper layer*. As stated in McTeer, "the aluminum wetting layer is consumed, thereby forming a Cu_nAl alloy layer 6 wherein n is an integer from about 0.5 to about 4." (column 18, lines 15-18). Thus, Claim 35 is not anticipated by this disclosure.

Importantly, there is no teaching or suggestion of a $Ti_xAl_yN_z$ layer, or any other metal nitride layer, doped with oxygen or other reactive species *and* covered with an aluminum wetting layer. Thus, in maintaining the rejections over McTeer, the Examiner appears to be combining the teaching of a $Ti_xAl_yN_z$ layer that is doped with oxygen with the *completely separate embodiment* in which McTeer teaches the use of an aluminum wetting layer. For a reference to be anticipatory, the elements must be arranged as required by the claim, although identical terminology does not have to be used. In re Bond 910 F.2d 831, 15 USPQ2d 1566 (Fed. Cir. 1990). Applicants respectfully submit that when the Examiner relies on a combination of elements, as he does here, a rejection based on anticipation is not appropriate. As pointed out in the M.P.E.P.§706.02, when a rejection requires that the reference teachings must be modified in order to meet the claims, the rejection is properly a rejection for obviousness under §103.

In appropriate circumstances, a single prior art reference can render a claim obvious. See, e.g., B.F. Goodrich Co. v. Aircraft Braking Sys. Corp., 72 F.3d 1577, 1582, 37 USPQ2d 1314, 1318 (Fed. Cir. 1996); In re O'Farrell, 853 F.2d 894, 902, 7 USPQ2d 1673, 1680 (Fed. Cir. 1988). However, it is well established that when a rejection for obviousness depends on a combination of elements, there must be motivation to combine those particular elements. "There must be evidence that 'a skilled artisan, confronted with the same problems as the inventors and with no knowledge of the claimed invention, ***would select the elements*** from the cited prior art references for combination in the manner claimed.'" In re Rouffet, 149 F.3d 1350, 1357, 47

U.S.P.Q.2d 1453, 1456 (Fed. Cir. 1998); *see also,* In re Werner Kotzab, 217 F.3d 1365, 1371, 55 U.S.P.Q.2d 1313, 1317 (Fed. Cir. 2000). As a result, in the present case the Examiner must show motivation to combine the various elements to achieve the claimed invention.

Here, there is no teaching or suggestion to combine oxygen doping from one embodiment (Column 17, lines 40-48) with the disclosure of an aluminum wetting layer from another embodiment (Column 17, line 59 through Column 18, line 27). Thus, one of skill in the art would not be motivated to utilize an aluminum wetting layer over a $Ti_xAl_yN_z$ barrier layer that has been annealed in an oxygen environment. Similarly, one of skill in the art would not be motivated to dope one of the "typical barrier layers" disclosed for use in the second embodiment with oxygen. While McTeer does state that $Ti_xAl_yN_z$ barrier layers "having the atomic composition described above in the description of Figure 1" are preferred for use in the second embodiment comprising the aluminum wetting layer, this is not a suggestion that the $Ti_xAl_yN_z$ layer is doped with oxygen. Rather, the "atomic composition" is given explicitly at column 17, lines 24-34 and *does not include oxygen*. Thus, no metal compound that would stuff grain boundaries can be identified.

Further, even if the necessary motivation were to be shown, *the combination of elements would not meet the claim limitations* as the resulting barrier layer would not have grain boundaries stuffed with a compound of a reactive metal that is different from each component of the metal nitride. In particular, even if the oxygen from an oxygen doped $Ti_xAl_yN_z$ layer were able to react with aluminum from an aluminum wetting layer, the grain boundaries of the nitride would not be stuffed with a metal compound of a reactive metal *different from each component of the metal nitride* as claimed. This is because the reactive metal, aluminum, is a component of the metal nitride.

In this regard, it is important that, as mentioned above, there is absolutely no teaching or suggestion anywhere in McTeer of doping *any* metal nitride layer, other than $Ti_xAl_yN_z$, with oxygen or other reactive species. The ***only*** teaching in McTeer with regard to doping is directed specifically to oxygen $Ti_xAl_yN_z$ layers. In finding that "...McTerr [sic] describes in col. 17 lines 62 to 66 describes [sic] several metal nitride layers including any metal nitride layer, and this includes other metal nitride [sic] than the metal in the reactive metal layer," it appears that the Examiner has not appreciated this point and has concluded that *any* metal nitride can be doped

with oxygen as disclosed for $Ti_xAl_yN_z$ at column 17, lines 45-55. Again, the only relevant teaching in McTeer of doping at all is very specific to oxygen-doping the $Ti_xAl_yN_z$ layer and there is no suggestion or motivation to dope other layers.

Further, there is no teaching in McTeer of utilizing any metal as a wetting layer other than aluminum. While the Examiner points to column 18, lines 48-49 for the teaching of the use of other refractory metals, this teaching is directed to metals that can be deposited directly over the silicon substrate to form a metal silicide. There is no teaching or suggestion that these other metals can be used in place of aluminum in the embodiment in which an aluminum wetting layer is deposited over a metal nitride layer. In fact, one of skill in the art would not replace aluminum with one of these other metals because it is the specific properties of aluminum that facilitate the reflowing of copper.

The Examiner argues that "McTerr [sic] teaches its metal nitrides has [sic] grain boundaries that are stuffed with a metal compound of the reactive metal because McTerr teaches similar process [sic] as described in application specification page 6 (Para 0033) lines 8 to 13 etc. ... using the same materials for the same purposes..." Applicants disagree, and submit that, as discussed above, McTeer does not teach the same process described in the present application. Further, McTeer has no recognition of the advantages of stuffing grain boundaries and makes no mention of grain boundaries. Thus, McTeer can not have the same purpose.

As McTeer does not teach the claimed barrier layer, inherently or otherwise, Applicants submit that the current rejection under 35 U.S.C. §102(e) should be withdrawn. Further, as there is no teaching or suggestion to combine the teaching of an oxygen-doped metal nitride layer with the teaching of an aluminum wetting layer, applicants submit that a rejection under 35 U.S.C. §103 would not be appropriate either. In any event, such a combination would not teach the claimed barrier layer.

Claims 36-37, 39-41 and 45-49 depend from Claim 35. Thus, the rejection of these dependent claims should be withdrawn as well. Applicants note that with respect to the individual rejections, the Examiner has referred to disparate teachings in McTeer (oxygen doping for one embodiment and use of an aluminum wetting layer for a distinct embodiment) without providing any motivation for the combination.

With respect to independent Claim 50, the Examiner indicates that it is rejected for the same reasons as Claim 35. As discussed above, McTeer does not teach or suggest a diffusion barrier with stuffed grain boundaries. Further, the Examiner refers to Figure 9 as anticipating the claimed structure. Figure 9 does not teach a first metal nitride layer, a layer of reactive metal over the first layer of metal nitride, and a second layer of metal nitride over the layer of reactive metal. Claim 51 depends from Claim 50. Thus, Applicants submit that the rejection of Claims 50-51 should be withdrawn.

With respect to Claim 52, the Examiner indicates that the teaching of a $Ti_xAl_yN_z$ layer doped with oxygen (column 17, lines 40-52) is anticipatory. Applicants submit that, as discussed in detail above, this disclosure does not teach or suggest that the $Ti_xAl_yN_z$ layer is covered by a layer of aluminum, as claimed. Claim 54 depends from Claim 52. Thus, Applicants request withdrawal of the rejection of Claims 52 and 54 under 35 U.S.C. §102.

Interestingly, the Examiner has found that Claims 56-58 are anticipated by McTeer. However, these Claims depend from Claim 55, which was rejected under 35 U.S.C. §103 as obvious in view of McTeer and Ayoyama et al. (U.S. Patent No. 5,592,024). Thus, Applicants treat the rejection of Claims 56-58 below.

Claim Rejections Under 35 U.S.C. §103

Claims 43, 44 and 55 were rejected under 35 U.S.C. §103(a) as unpatentable over McTeerin view of Aoyama (U.S. Patent No. 5,592,024). As discussed above, Claims 56-58 depend from Claim 55. Thus, although they were indicated to be anticipated only by McTeer, Claims 56-58 are addressed here.

Claims 43 and 44 depend from Claim 35. In view of the patentability of Claim 35, as described above, Applicants submit that the rejection of Claims 43 and 44 should be withdrawn.

With respect to Claim 55, the Examiner indicates, without explanation, that the claim is obvious over the teachings in McTeer, as applied to Claim 35 above, in view of the teaching in Aoyama of a silicon dioxide insulating film. Applicants respectfully submit that, as discussed above, there is no teaching in McTeer of a diffusion barrier comprising metal nitride with stuffed grain boundaries, much less with grain boundaries stuffed with silicon oxide. This deficiency is

not made up for by Aoyama. Claims 56-58 depend from Claim 55. Thus, Applicants request withdrawal of the rejection of Claims 55-58.

Claim 53 stands rejected as obvious over the combination of McTeer, Ayoyama et al. (U.S. Patent No. 5,592,024) and Dutta (U.S. Publication 2002/64592). Claim 53 depends from Claim 52. In view of the patentability of Claim 52, discussed above, Applicants request withdrawal of the present rejection.

Conclusion

In view of the arguments presented above, Applicants submit that the present application is in condition for allowance. If any issues remain, the Examiner is cordially invited to contact Applicants' representative at the number provided below in order to resolve such issues promptly.

Respectfully submitted,

KNOBBE, MARTENS, OLSON & BEAR, LLP

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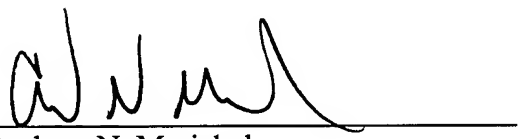
By: 

Andrew N. Merickel
Registration No. 53,317
Attorney of Record
Customer No. 20,995
(415) 954-4114

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